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Handbook

Retrofitting POTWs

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existing POTW. The evaluator should continuously be asking "How does this affect plant performance?" If the area of inquiry is directly related to plant performance, such as a clarifier design or an administrative policy to cut electrical costs to an unreasonable level, the evaluator should spend sufficient time and effort to fully understand and define the effect on plant performance. If the area of inquiry is not directly related to plant performance, such as the appearance of the grounds, the condition should be noted and efforts directed toward areas that specifically impact performance.

Completion of Form D-3 requires that values be selected to represent current plant hydraulic and BOD_5 loadings. Typically, data for the most recent 12 months are used.

2.3.3 Evaluation of Major Unit Processes

Early in the on-site activities, an evaluation of the POTW's major unit processes is conducted to determine the performance potential of existing facilities at current loadings (i.e., define the facility as Type 1, 2, or 3 as described in Section 2.2). The three unit processes whose capabilities most frequently affect biological wastewater treatment plant performance are: the aerator, the secondary clarifier, and the sludge handling system (1,15,16).

A point system is used to quantify the evaluation of these three basic unit processes. Key loading and process parameters are calculated and results for each parameter assigned points by comparison with standard tables. Subsequently, each of the three major unit processes receives a total score by adding together the value of the points assigned the loading and process parameters. The totals are then compared with standards to assess whether a Type 1, 2, or 3 capability is indicated for that unit process (see Figure 2-1). The overall plant type is determined by the "weakest link" among the three major process areas. It must be remembered in using this point system that this simplification can provide valuable assistance but cannot replace the overall judgment and experience of the evaluator.

2.3.3.1 Suspended Growth Major Unit Processes

Suspended growth facilities include those plants using variations of the activated sludge process. The three significant unit processes within these types of facilities that determine capacity and performance are the aeration basin, secondary clarifier, and sludge handling system.

a. Aeration Basin

Parameters that are used for scoring the capability of an aeration basin are: hydraulic detention time, BOD_5 loading, and oxygen availability. The point system for scoring these parameters is presented in Table 2-2. To obtain the necessary parameters, information is required on wastewater flow to the aeration basin, aeration basin BOD_5 loading, aeration basin liquid volume, and oxygen transfer capacity.

Table 2-2. Parameters for Scoring Capability of Aeration Basins in Suspended Growth POTWs*

Current Operating Condition	Points	Points
Hydraulic Detention Time, hr:		
24	10 (max.)	
10	6	
5	0	
3	-6	
BOD_5 Loading, kg/m³/d (lb/d/1,000 cu ft):		
0.24 (15)	10 (max.)	
0.40 (25)	6	
0.80 (50)	0	
1.28 (80)	-6	
Oxygen Availability, kg O_2/kg BOD_5 applied:	w/ nitrification	w/o nitrification
2.0	10 (max.)	10 (max.)
1.5	5	10 (max)
1.2	0	5
1.0	-5	0
0.8	-10	-5
0.6	-10	-10

* Interpolate to nearest whole number between loadings listed.

Oxygen transfer capacity is usually the most difficult information to obtain if the original engineering data are not available or if there is some reason to question the original design data based on current conditions. Generally, the evaluation proceeds by using available data on oxygen transfer capacity and assuming it is correct unless the transfer capacity appears to be marginal. If oxygen transfer capacity appears marginal, further investigation is warranted. Any of the following conditions would lead an evaluator to suspect marginal oxygen transfer:

- Difficulty in maintaining minimum desired dissolved oxygen concentrations in the aeration basin
- Continuous operation of all blowers or all aerators set at high speed
- Design data showing less than 1.2 kg oxygen transfer capacity per kg actual BOD_5 load

If design oxygen transfer numbers are unavailable or are believed suspect, oxygen transfer rates presented in Table 2-3 can be used to estimate oxygen transfer capacities.

Typically, the oxygen transfer efficiency (percent) is used when evaluating different diffused air systems, and oxygen transfer rate (lb O_2/hp-hr) is used when evaluating surface mechanical aerators. The evaluation of both diffused air and surface mechanical aerators is described in more detail below.

Table 2-3. Typical Clean Water Standard Oxygen Transfer Values

System	Oxygen Transfer Efficiency[a]	Oxygen Transfer Rate[b]
	percent	lb/wire hp-hr
Fine bubble diffusers, total floor coverage	28-32	6.0-6.5
Fine bubble diffusers, side wall installation	18-20	3.5-4.5
Jet aerators (fine bubble)	18-25	3.0-3.5
Static aerators (medium-size bubble)	10-12	2.3-2.8
Mechanical surface aerators	-	2.5-3.5
Coarse bubble diffusers wide band pattern	8-12	2.0-3.0
Coarse bubble diffusers, narrow band pattern	6-8	1.5-2.0

[a] at 15 feet submergence.
[b] 1 lb/hp-hr = 0.61 kg/kW-hr.

When evaluating oxygen transfer capability of diffused aeration systems it is necessary to assess the capacity of the aeration blowers and the standard transfer efficiency of the diffusers. This information is often available from O&M manuals, specifications, and manufacturers literature. If questionable information is available, typical values for various systems are shown in Table 2-3. The blower capacity and diffuser transfer efficiency can then be utilized to determine the amount of oxygen (lb/d) that can be transferred into the wastewater by the existing aeration system.

To determine the aeration system oxygen transfer in lb/day, the diffuser standard transfer efficiency or standard oxygen transfer rate at standard conditions (14.7 psia, 20°C, and clean water) must be converted to transfer efficiency at actual site conditions including adjustments for site elevation, wastewater temperature, and wastewater characteristics. The procedure to convert standard oxygen transfer rates to actual oxygen transfer rates is presented in Appendix E.

In addition, blower capacity must be determined in standard cubic feet per minute (SCFM) to determine the mass of air/oxygen that the blowers are capable of discharging. There is not a standard method of presenting blower output. Some manufacturers provide the blower rating in standard cubic feet per minute (SCFM), which is a term that describes airflow at standard conditions of 14.7 psia and 20°C. It is noted that different air temperatures, such as 70°F, are used by other manufacturers to describe standard conditions. Also, the blower output rating is often presented in terms of ICFM (inlet cfm) or ACFM (actual cfm), which is CFM at site conditions. ICFM, ACFM, or SCFM at standard conditions other than the conditions chosen for the evaluation must be converted to SCFM. The procedure to convert ICFM or ACFM to SCFM for the standard condition of 14.7 psia, 20°C and clean water, is presented in Appendix E.

Utilization of the procedures presented in Appendix E to calculate the oxygen transfer capability of a diffused air system is shown in the following example.

In Plant A there are four centrifugal blowers, each with a capacity of 1,550 acfm. Three are utilized, with one as standby. The standard oxygen transfer efficiency (SOTE) or efficiency of the coarse bubble diffusers is 12 percent at 15-ft water depth based on manufacturer's data. Plant A is located at 2,750 feet above sea level.

1. Convert SOTE = 12 percent to AOTE using:

$$\mathrm{AOTE} = (\mathrm{SOTE})\,\alpha\left[\frac{\beta\,C_{sw} - C_L}{C_s}\right]\theta^{T-20}$$

Where,

AOTE = actual oxygen transfer efficiency at site conditions, percent.
SOTE = standard oxygen transfer efficiency at standard conditions in clean water, percent.
α = 0.85 for coarse bubble diffuser, from Table E-1.
β = 0.95 for domestic wastewater.
θ = 1.024
C_s = 9.17 mg/L oxygen saturation at standard temperature and pressure.
C_{sw} = $C_{14.7}$ (P/14.7), mg/L

Assume maximum summer wastewater temperature = 25°C at Plant A. From Table E-2, $C_{14.7}$ = 8.38 mg/L @ 25°C. From Figure E-1, P = 13.25 psia @ 2,750 ft above mean sea level. A potential depth correction can be applied to this term, as noted in Appendix E. However, to be more conservative in the evaluation, utilize atmospheric pressure:

$$C_{sw} = 8.38\ [13.25/14.7] = 7.55\ \mathrm{mg/L}$$

C_L = 2.0 mg/L (mixed liquor DO concentration)

$$\mathrm{AOTE} = \{(0.12)(0.85)\ [(0.95)(7.55)-2]\ 1.024^{25-20}\} \div 9.17$$

$$\mathrm{AOTE} = 6.5\ \text{percent}$$

2. Convert blower output of 1,550 acfm to scfm:

$$\mathrm{acfm} = \mathrm{scfm}\ (T_a/T_s)(P_s/P_a)$$

Where,

acfm = 1,550 cfm.

T_a = 100°F + 460°F = 560°R (temperature at which manufacturer rated blowers).
T_s = 68°F + 460°F = 528°R (standard temperature).
P_s = 14.7 psia (standard pressure).
P_a = 13.25 psia (pressure @ 2,750 ft above mean sea level).

scfm = (1,550) (528/560) (13.25/14.7) = 1,317 cfm

3. Calculate lb O_2/d from 3 blowers using diffuser actual oxygen transfer efficiency of 6.5 percent and blower capacity of 1,317 cfm:

Peak air flow = 3 x 1,317 = 3,951 scfm

lb O_2/d = (scfm)(1,440 min/d)(23.2 lb O_2/100 lb air) x (0.075 lb air/cu ft air)(AOTE)

= (3,951)(1,440)(23.2/100)(0.075)(6.5)

= 6,435 lb/d

4. Therefore, 3 blowers @ 1,317 cfm each will transfer 6,435 lb O_2/d. Compare the oxygen transfer capability with the BOD_5 loading applied to determine the lb O_2/lb BOD_5 that the diffused air system can provide.

When evaluating the oxygen transfer capability of a surface mechanical aeration system, the power usage of the motor (whp) and the oxygen transfer rate of the aerator (lb O_2/whp-hr) must be determined. Various techniques for estimating motor power usage based on actual power measurements are presented in Appendix F. If power measuring equipment is not available, wire horsepower may be estimated by assuming the motor is 90 percent efficient and the surface mechanical aerator gear box is 85 percent efficient. Using these estimates, the evaluator may assume that 75 (appropriately 0.9 x 0.85) percent of the motor horsepower (mhp) is being converted to oxygen transfer energy, or wire horsepower. For example, if a surface mechanical aerator motor is rated at 50 mhp, the wire horsepower could be estimated to be 0.75 x 50 = 37.5 whp. Actual power measurements should be taken if the oxygen transfer capability of the system determined by estimating wire horsepower appears inadequate.

The aerator oxygen transfer rate may be determined from the O&M manual, specifications, and equipment manufacturer's literature. If questionable information is available, a typical value for surface mechanical aeration systems can be found in Table 2-3. The standard oxygen transfer rate (SOTR) is typically provided and this must be converted to the actual oxygen transfer rate (AOTR) as shown in Appendix E. Utilization of the procedures presented in Appendices E and F to determine actual oxygen transfer rate and motor wire horsepower are presented in the following example.

In Plant B there are two 50-hp surface mechanical aerators. Both units are utilized. The SOTR is 3 lb O_2/whp-hr based on manufacturer's data. Plant B is located at 2,750 ft above sea level.

1. Convert SOTR = 3 lb O_2/whp-hr to AOTR using

$$AOTR = (SOTR)\,\alpha \left[\frac{\beta C_{sw} - C_L}{C_s} \right] \theta^{T-20}$$

Where,

AOTR = actual oxygen transfer rate at site conditions, percent.
SOTR = standard oxygen transfer rate at standard conditions in clean water, percent.
α = 0.90 for surface mechanical aerator, from Table E-1.
β = 0.95 for domestic wastewater.
θ = 1.024
C_s = 9.17 mg/L oxygen saturation at standard temperature and pressure.
C_{sw} = $C_{14.7}$ (P/14.7), mg/L

Assume maximum summer wastewater temperature = 25°C at Plant B. From Table E-2, $C_{14.7}$ = 8.38 mg/L @ 25°C. From Figure E-1, P = 13.25 psia @ 2,750 feet above mean sea level.

C_{sw} = 8.38 [13.25/14.7) = 7.55 mg/L

C_L = 2.0 mg/L (mixed liquor DO concentration)

AOTR = {(3)(0.9) [(0.95)(7.55)-2] 1.024^{25-20}} ÷ 9.17

AOTR = 1.7 lb O_2/whp-hr

2. Determine surface mechanical motor power usage:

a. Determine whp of motor based on the assumption that whp is 75 percent of mhp.

whp = 0.75 (50 mhp) = 37.5 whp

b. Determine whp based on actual power measurements and assumption that power factor is 0.90, as shown in Appendix F.

Voltage measurement = 480 volts

Amperage measurement = 37.4 amps

kVA = (V) (A) $(3)^{1/2}$ ÷ 1,000 (3-phase power)
= (480) (37.4) $(3)^{1/2}$ ÷ 1,000 = 31.1kW

$kW = kVA \times PF = 31.1\ (0.9) = 28\ kW$

$whp = kW \div 0.746 = 28 \div 0.746 = 37.5\ hp$

$\text{Total } whp = 2 \text{ motors} \times 37.5\ whp = 75\ whp$

3. Determine oxygen transferred based on AOTR and whp:

$$O_2 \text{ transfer} = (1.7 \text{ lb } O_2/\text{whp-hr})\ (75 \text{ whp})\ (24 \text{ hr/d}) = 3{,}060 \text{ lb } O_2/d$$

4. Compare the oxygen transfer rate with the plant BOD_5 applied loading to determine the lb O_2/lb BOD_5 that the surface mechanical aeration system can provide.

Once data are available on wastewater flows, BOD_5 of influent to the aeration basin, aeration basin volume, and oxygen transfer capacity, the following calculations should be completed by the evaluator:

Aerator Hydraulic Detention Time =
Aeration Basin Vol. ÷ Peak Month ADWF

Peak month average daily wastewater flow is typically for the most recent 12 months. Peak month flow is used to ensure that the aerator is capable of meeting monthly average effluent requirements.

BOD_5 Loading =
BOD_5 Applied Loading ÷ Aeration Basin Volume

BOD_5 loading is typically the daily average value for the most recent 12 months. Peak value is not used since aerator capability is not as sensitive to "normal" BOD_5 loading variations.

Oxygen Availability =
Oxygen Transfer Capacity ÷ BOD_5 Applied Loading

When the above calculations have been completed for the subject POTW, the results are compared to the values given in Table 2-2 and appropriate points are assigned each parameter. If the parameters for the subject POTW fall between the values listed, interpolation is used to assign appropriate points.

b. Secondary Clarifiers
Parameters that are used for scoring the capability of suspended growth secondary clarifiers are: configuration, surface overflow rate (SOR), depth, return sludge removal mechanism, and return sludge control. The scoring system for these parameters is presented in Table 2-4.

The configuration score is applied to assist in assessing those clarifiers that have diminished capabilities due to poor weir locations or poor surface development with weirs. For example, a clarifier 15-m long and 3-m wide (total surface area of 45 m²) with a two-sided 1-m wide weir located 1 m from the end is judged to have 9 m² of launder coverage [(3 m wide) x (1 m + 1 m + 1 m)], or only 20 percent of the surface area developed. This clarifier's score would be low because of the configuration.

Table 2-4. Parameters for Scoring Capability of Clarifiers in Suspended Growth POTWs

Current Operating Condition	Points
Configuration	
Circular with "donut" or interior launders	10
Circular with weirs on walls	5
Rectangular with 33% covered with launders	5
Rectangular with 20% covered with launders	0
Rectangular with launder at or near end	-10
Surface Overflow Rate, $m^3/m^2/d$ (gpd/sq ft)[1]:	
12 (300)	15
20 (550)49 (1,200)	10
27 (650)	5
33 (800)	0
41 (1,000)	-10
49 (1,200)	-15
Depth at Weirs, m (ft):	
4.6 (15)	10
3.7 (12)	4
3.0 (10)	0
2.4 (8)	-5
2.1 (7)	-10
Return Sludge Removal:	
Circular, rapid withdrawal	10
Circular, scraper to hopper	8
Rectangular, cocurrent scraper	2
Rectangular, countercurrent scraper	0
No mechanical removal	-5
Return Activated Sludge Control:	
Actual RAS flow range completely within typical RAS flow range; capability to measure RAS flow	10
Actual RAS flow range completely within typical RAS flow range; no capability to measure RAS flow	7
50% of typical RAS flow range covered by actual RAS flow range; capability to measure RAS flow	5
50% of typical RAS flow range covered by actual RAS flow range; no capability to measure RAS flow	0
Actual RAS flow range completely outside typical RAS flow range	-5

Surface overflow rate is calculated independently of the configuration evaluation and is based on the total clarifier surface area, as follows:

SOR = Wastewater Flow from the Clarifier
÷ Clarifier Surface Area

Typically, the peak month daily average wastewater flow for the most recent 12 months is used to calculate SOR. Peak flow is used to ensure that clarifier is capable of meeting monthly average effluent requirements.

Note: If diurnal flow variations are greater than 2:1 (peak daily flow:daily average flow) the points for SOR must be adjusted to lower values. Conversely, if a clarifier is loaded at a relatively constant rate due to the availability of flow equalization, the points for SOR can be adjusted upward. It must be remembered that the assessment is not a design evaluation but an assessment of whether the clarifier can be made to perform under the desired conditions. In POTWs where special allowance has been made for high infiltration/inflow, such as permitted bypassing above a certain flow, the flow at which secondary treatment is required should be used.

Depth and return sludge removal scores are derived by comparing existing facilities with the conditions shown in Table 2-4. Evaluation of return activated sludge control is based on the ability to control the return flow rate within the typical range for the particular type of activated sludge plant. Typical ranges for return activated sludge pumping rates are presented in Table 2-5.

Table 2-5. Typical Ranges for Return Activated Sludge Pumping Capacities

Process Type	Return Activated Sludge
	% of average daily wastewater flow
Conventional A. S. and Activated Bio-filters (plug flow or complete mix)	25-100
Extended Aeration (including oxidation ditches)	50-100
Contact Stabilization	50-125

c. Sludge Handling Capability

The capability of sludge handling facilities associated with an activated sludge plant is scored by the controllability of the wasting process and the capability of the available sludge treatment and ultimate disposal facilities. Scoring for sludge handling capability is not straightforward because existing facilities cannot be easily assessed due to the variability that exists in design and operational "standards" for unit process capability. To evaluate the sludge handling capability, the evaluator must first calculate expected sludge production based on current loadings to the wastewater treatment processes. The evaluator then assesses the capability of the existing sludge facilities to handle the expected sludge production.

The criteria and point system for evaluating sludge handling capability are presented in Table 2-6. As indicated by the lower points allocated, controllability is much less important than capacity.

Table 2-6. Criteria for Scoring Sludge Handling Capability for Suspended Growth POTWs

Current Operating Condition	Points
Controllability:	
Automated sampling and volume control	5
Metered volume and hand sampling	3
Hand measured volume and hand sampling	2
Sampling or volume measurement by hand not practical	0
Capability:	
150% of calculated sludge production	25
125% of calculated sludge production	20
100% of calculated sludge production	15
75% of calculated sludge production	0
50% of calculated sludge production	-10

Controllability of the wasting process is indicated by the type of waste sludge volume measurement and the type of waste sludge sampling available. The optimum control for an activated sludge wasting system includes automatic volume control and automatic sampling. A positive displacement pump and automatic sampler, both controlled by an accurate and precise clock, is an example of this type of control.

Most small activated sludge plants can manually measure a wasted volume (depth increase in holding tank or digester, or the number of tank trucks filled) and manually sample (from a tap or the open end of the waste sludge line). Most larger plants have flow measuring and totaling devices on waste sludge lines.

Capability of existing sludge handling facilities is evaluated using the following procedures:

- Determine current plant loadings and calculate expected sludge production.
- Establish capability of existing sludge handling unit processes.
- Determine percentage of the expected sludge production each unit process can handle.
- Identify the "weakest link" process as the overall capability of the existing sludge handling facilities and compare to scoring values in Table 2-6.

Expected sludge production is calculated using current BOD_5 loadings (unless believed inaccurate) and typical unit sludge production values for the existing wastewater treatment processes (17). Typical unit sludge production values for various processes are shown in Table 2-7. For example, an oxidation ditch removing about 1,000 kg BOD_5/d would be expected to have an average sludge production of about 650 kg TSS/d (1,000 kg BOD_5/d x 0.65 kg TSS/kg BOD_5 removed).

When plant records include sludge production data, the actual unit sludge production value should be compared to the typical value. If a discrepancy greater than 15 percent exists between these values, further

Table 2-7. Unit Sludge Production Values for Projecting Sludge Production From Suspended Growth POTWs

Process Type	kg TSS (sludge)/ kg BOD_5 removed
Activated Sludge w/Primary Clarification	0.7
Activated Sludge w/o Primary Clarification	
Conventional[a]	0.85
Extended Aeration[b]	0.65
Contact Stabilization	1.0

[a] Includes tapered aeration, step feed, plug flow, and complete mix with wastewater detention times < 10 hours.
[b] Includes oxidation ditch.

Table 2-8. Sludge Concentrations for Projecting Sludge Production From Suspended Growth POTWs

Sludge Type	Waste Concentration
	mg/l
Primary	50,000
Activated	
Return Sludge/Conventional	6,000
Return Sludge/Extended Aeration	7,500
Return Sludge/Contact Stabilization	8,000
Return Sludge/small plant with low SOR[a]	10,000
Separate waste hopper in sec. clarifier	12,000

[a] Returns can often be shut off for short periods to thicken waste sludge in clarifiers with SORs less than 20 $m^3/m^2/d$ (500 gpd/sq ft).

evaluation is warranted. If actual plant data fall within the 15 percent range, these data can be used for the evaluation of sludge handling capability. A detailed example of calculating expected sludge production and comparing it with plant data is included in Section 2.3.5.

Often plant sludge production data is not reliable and cannot be used to accurately assess sludge handling capability. The most common causes of inaccurate recorded sludge production are:

- Excessive solids loss over the final clarifier weirs
- Inaccurate waste volume measurement
- Insufficient waste sampling and concentration analyses
- Inaccurate determination of BOD_5 removed

Using the unit sludge production values and projected desired BOD_5 removals for the subject plant (desired effluent BOD_5 should meet effluent requirements), the expected mass of sludge produced per day can be calculated. To complete the scoring of sludge handling capability, the expected volume of sludge produced per day must also be calculated. Typical waste sludge concentrations for activated sludge plants are presented in Table 2-8 and can be used to convert the expected mass of sludge produced per day to the expected volume of sludge produced per day.

Variations in sludge production values have been observed throughout the year. Additionally, operation decisions to lower sludge inventories in the plant can place increased requirements on the sludge handling facilities. It is not uncommon for these variations to require 125-150 percent of the long-term average sludge production value (17). <u>For this reason, a factor of 1.25 is applied to the calculated sludge mass and volume values to ensure reliable capability under most operational situations throughout the year</u>.

The capability of each of the components of the sludge handling process are evaluated with respect to its ability to handle the calculated sludge production based on current loadings (the mass and volume values adjusted by the 1.25 factor are used in this evaluation). Using this evaluation approach, sludge handling "bottlenecks" can be identified.

Typical components found in activated sludge facilities are: thickening, digestion, dewatering, hauling, and disposal. Guidelines for the capability evaluation of the components of the existing sludge handling processes are provided in Tables 2-9 and 2-10. The guidelines provided in Table 2-9 are used to compare existing facility capability to calculated sludge production. For example, an exist-ing aerobic digester with a volume of 380 m^3 (100,000 gal) in a plant with a calculated waste sludge volume of 19 m^3/d (5,000 gpd) would have a hydraulic detention time of 20 days. This is 133 percent of the guidelines (15 days) provided for aerobic digesters in Table 2-9. Thus, this compo-nent of the sludge handling process in this particular POTW would have capability for 133 percent of the calculated sludge production. If the aerobic digester proved to have the lowest capability to handle the calculated sludge production of all the components of the sludge handling processes in this POTW, sludge handling capability would score 22 points (interpolated from Table 2-6). The sludge handling capability evaluation is illustrated as part of the CPE example presented in Section 2.3.8.

d. Suspended Growth Major Unit Process Analysis
A worksheet is presented in Appendix L to facilitate the suspended growth major unit process evaluation. Once individual major unit processes are evaluated and given a score, these results should be recorded on a summary sheet, as shown in Table 2-11, and compared with standards for each major unit process and the total plant. This analysis results in the subject POTW being rated a Type 1, 2, or 3 facility, as described in Section 2.2.1.1. The sum of the points scored for aeration basin, secondary clarifier, and sludge handling capability must be 60 or above for the subject POTW to be designated a Type 1 facility.

Furthermore, regardless of total points, the aerator must score at least 13 points, the secondary clarifier at least 25 points, and sludge handling capability at least 10 points for the plant to be considered Type 1.

If the subject POTW meets the criteria for a Type 1 plant, the evaluation has indicated that all major processes have adequate capability for the plant to provide desired performance. If the total is less than 60 points, or if any one major unit process scores less than its minimum, the facilities must be designated as Type 2 or 3.

The minimum criteria for a Type 2 plant are 20 total points and zero for each individual process. If the total is less than 20, or if any major process scores a negative value, the POTW must be considered inadequate and the plant designated as Type 3. Type 3 plants generally require major modifications before they can be expected to meet secondary treatment effluent limits.

Table 2-9. Guidelines for Evaluating Capability of Existing Sludge Handling Processes[a]

Process	Parameters That Can Be Used to Represent 100% of Required Sludge Handling Capability[b]
Gravity Thickeners	
Primary Sludge	125 kg/m²/d (25 lb/d/sq ft)
Activated Sludge	20 kg/m²/d (4 lb/d/sq ft)
Primary + Activated	50 kg/m²/d (10 lb/d/sq ft)
Fixed Film	40 kg/m²/d (8 lb/d/sq ft)
Primary + Fixed Film	75 kg/m²/d (15 lb/d/sq ft)
Dissolved Air Flotation	
Activated Sludge	50 kg/m²/d (10 lb/d/sq ft)
Primary + Activated	100 kg/m²/d (20 lb/d/sq ft)
Fixed Film	75 kg/m²/d (15 lb/d/sq ft)
Primary + Fixed Film	125 kg/m²/d (25 lb/d/sq ft)
Digesters	
Aerobic	15 days' HDT[c]
Anaerobic	
Single Stage	40 days' HDT
Two Stage	30 days' combined HDT
Drying Beds	Worst season turnover time
Mechanical Dewatering	
Single Unit	30 hours of operation/week
Multiple Units	60 hours of operation/week (with one unit out of service)
Liquid Sludge Haul	
Short Haul (<3 km)	6 trips/day maximum
Long Haul (>20 km)	4 trips/day maximum

[a] These guidelines are not developed to meet the proposed new Federal sludge regulations.
[b] Capability of existing unit processes should not be downgraded to these values if good operation and process performance are documented at higher loadings. For example, if records appear accurate and show that all sludge production has been successfully thickened in a gravity activated sludge thickener for the past year at an average loading of 25 kg/m²/d (5 lb/d/sq ft), the existing thickener should be considered to have 100% of required capability.
[c] HDT = Hydraulic detention time = Volume of digester ÷ Volume of waste sludge calculated to be produced.

Table 2-10. Miscellaneous Unit Values Used in Evaluating Sludge Handling Capability[a]

	Digester HDT[b]	Total Solids Reduction	Output Solids Conc.
	days	%	mg/l
Aerobic Digesters Following Extended Aeration (MCRT >20 d)	10	10	12,000
	15	20	15,000
	20	30	17,000
	>30	35	20,000
Aerobic Digesters Following Conventional A. S. (MCRT <12 d)	10	20	12,000
	15	35	15,000
	>20	40	17,000
Anaerobic Digesters for Activated + Primary, and Fixed Film + Primary (Supernating Capability Usable)	20	25	= input
	30	35	= input
	40	45	= input
WAS Volatile Solids Content			
Conv. (MCRT <12 d)		80%	
Ext. Aer. (MCRT >20 d)		70%	

[a] Values in table are intended for use in allowing an evaluation of sludge handling capability to proceed in the absence of available plant data. Many other variables can affect the values of the parameters shown.
[b] HDT = Hydraulic detention time = Volume of digester ÷ Volume of waste sludge expected to be produced.

A suspended growth POTW that scored the following during the evaluation of major unit processes would meet the criteria for a Type 3 plant:

	Points Scored	Points Required Type 1	Type 2	Type 3
Aeration Basin	14	13-30	0-12	<0
Secondary Clarifier	-8	25-55	0-24	<0
Sludge Handling	10	10-30	0-9	<0
Total	16	60-115	20-59	<20

The point system in Table 2-11 has been developed to aid in assessing the capability of a POTW's major physical facilities. It cannot replace the overall judgment and experience of the evaluator, which should be the deciding factor in determining the capability of facilities to provide improved performance.

2.3.3.2 Fixed Film Major Unit Processes

Fixed film facilities covered in this manual include those trickling filter plants using rock or plastic media plus those using the RBC or activated bio-filter (ABF) variations of the basic process. The unit process in fixed film wastewater treatment plants that most significantly affects capacity and performance is the "aerator" portion of the plant (i.e., the amount and type of trickling filter media, RBC media, etc.) Other significant unit processes are the secondary clarifier and sludge handling capability.

Table 2-11. Suspended Growth Major Unit Process Capability Evaluation

	Points Scored	Points Required*		
		Type 1	Type 2	Type 3
Aeration Basin	_____	13-30	0-12	<0
Secondary Clarifier	_____	25-55	0-24	<0
Sludge Handling	_____	10-30	0-9	<0
Total	_____	50-115	20-59	<20

* Each unit process as well as the overall points must fall in the designated range for the plant to achieve the Type 1 or 2 rating.

a. Aerator

Trickling Filters

An approach to develop "equivalency" is used to allow a comparable evaluation of the potential performance capability of trickling filters of varying media types. It is not intented that this equivalency approach be used as a basis of design. The unit surface area for common rock media is typically 43 m^2/m^3 (13 sq ft/cu ft) (3). This information can be used to convert data from trickling filters with artificial media to roughly equivalent volumes of common rock media. For example, 1,000 m^3 (3,500 cu ft) of a plastic media with a specific surface area of 89 m^2/m^3 (27 sq ft/cu ft) is roughly equivalent to [(89/43) x (1,000 m^3)] or 2,070 m^3 (7,300 cu ft) of common rock media. Unit surface area information for various media types is generally available in manufacturers' literature.

Using the equivalency calculation, BOD_5 loadings can be calculated for all types of media. Loadings for trickling filters are typically expressed as mass of BOD_5 per volume of media. The volumetric loading can be calculated using the equivalency calculation presented above. Results can be compared with criteria in Table 2-12 to compute a "score" for the trickling filter.

The capability of a trickling filter can be significantly decreased if plugging occurs. Ponding on the filter is a common indicator of plugging and can be due to overgrowth of microorganism mass, disintegration of the media, or underdrain blockage or damage. The evaluator should inspect the filter in several places (removing media where possible) to ensure that ponding underneath the upper layer of rocks is not occurring.

RBCs

Parameters for scoring RBCs are presented in Table 2-13 (18). The key parameters to be evaluated are: BOD_5 loading on the first stage and on the entire system; number of stages provided; and whether or not sidestreams from anaerobic sludge treatment are received. BOD_5 loading used for evaluating RBCs is soluble BOD_5 ($SBOD_5$) per unit of media. If data are not available, $SBOD_5$ is estimated for typical domestic wastewater as 0.4 of the primary effluent total BOD_5 ($TBOD_5$). If significant industrial contributions are present in the system, $SBOD_5$ should be determined by testing.

Table 2-12. Parameters for Scoring Aerator Capability for Trickling Filter POTWs

Current Operating Condition	Points: Freezing Temp.[b]	Points: Covered Filter or Nonfreezing Temp.
BOD_5 Loading, kg $BOD_5/m^3/d$ (lb/d/1,000 cu ft):[a]		
0.16 (10)	20	20
0.32 (20)	15	20
0.48 (30)	0	10
0.80 (50)	-10	-5
1.12 (70)	-20	-10
Recirculation, ratio to raw flow:		
2:1	3	
1:1	2	
None	0	
Anaerobic Sidestreams:[c]		
Not returned to plant	0	
Returned to wastewater stream ahead of the TF:		
Returned to flow equalization tank or prior to primary clarifier	-6	
Returned directly ahead of TF	-10	

[a] Based on primary effluent and common rock media having a specific surface area of about 43 m^2/m^3 (13 sq ft/cu ft).
[b] Temperatures below freezing for more than one month.
[c] Supernatant from anaerobic digesters or filtrate/concentrate from the dewatering processes following anaerobic digesters.

Surface area data for RBCs are generally available in manufacturers' literature or in plant O&M manuals. If these sources are unavailable or do not contain the needed information, the manufacturer's representative or the manufacturer should be contacted to obtain the data.

First-stage media loading is calculated by dividing the mass of $SBOD_5$ going to the first stage by the total surface area of only the first-stage media. System media loading is calculated by dividing the total $SBOD_5$ load to the RBCs by the total surface area of all RBC media. In most cases, the mass of $SBOD_5$ will be the same for these calculations. They should only be different in plants where some of the $SBOD_5$ load is bypassed around the first stage.

ABFs

Parameters for evaluating ABF aerators are presented in Table 2-14 (19). The key parameters are: biocell BOD_5 loading and aeration basin detention time. A criterion of lesser importance is recirculation directly around the biocell.

Table 2-13. Parameters for Scoring Aerator Capability for RBC POTWs[a] (7)

Current Operating Condition	Points
First-Stage Loading, g $SBOD_5/m^2/d$ (lb/d/1,000 sq ft):	
12 (2.5)	10
20 (4.0)	0
29 (6.0)	-6
System Loading g $SBOD_5/m^2/d$ (lb/d/1,000 sq ft):	
2.9 (0.6)	10
4.9 (1.0)	0
7.3 (1.5)	-6
Number of Stages:	
4	10
3	7
2	4
Anaerobic Sidestreams:	
Not returned to plant	0
Returned to wastewater stream ahead of RBC	
Returned to flow equalization tank or prior to primary clarifier	-6
Returned directly ahead of RBC	-10

[a] Includes mechanical and air drive RBCs.
[b] Supernatant from anaerobic digesters or filtrate/concentrate from the dewatering processes following anaerobic digesters.

Table 2-14. Parameters for Scoring Aerator Capability for ABF POTWs (19)

Current Operating Condition	Points
Biocell BOD_5 Loading, kg $BOD_5/m^3/d$ (lb/d/1,000 cu ft):	
1.6 (100)	15
2.4 (150)	10
2.8 (175)	5
3.2 (200)	0
4.0 (250)	-5
4.8 (300)	-10
Aeration Basin Detention Time, hours:	
4	20
3	15
2	12
1	5
0.75	0
0.5	-10
Oxygen Availability in Aeration Basin, kg O_2/kg BOD_5 to Biocell:	
1.0	10
0.75	7
0.5	3
0.4	0
0.3	-15
Recirculation - Directly Around Biocell, ratio to raw flow:	
1:1	3
None	0

BOD_5 loadings on the biocell are calculated in a manner similar to trickling filter loadings: primary effluent BOD_5 mass is divided by the volume of the biocell media. Aeration basin detention time is calculated in a manner similar to activated sludge aeration basin hydraulic detention time: the aeration basin liquid volume is divided by the average daily wastewater flow. Sludge recirculation is not included in this calculation. Typically, peak month daily average flow for the most recent 12 months is used to ensure that adequate detention time exists to meet the monthly average effluent requirements.

Oxygen availability in the aeration basin of an ABF plant is calculated by dividing mass of oxygen transfer capacity by the total mass of BOD_5 applied to the biocell. This is done because the removal attributed to the biocell versus that occurring in the aeration basin is not easily distinguished. Most ABF plants provide for recirculation directly around the biocell. Recirculation is calculated as a ratio to raw flow (typically, the peak month daily average flow).

b. Secondary Clarifier

Criteria for scoring the capability of secondary clarifiers in trickling filter and RBC plants are presented in Table 2-15. The calculations require that wastewater flow rate and the clarifier configuration, surface area, and depth be known (see Section 2.3.3.1). For ABF plants, the criteria for suspended growth secondary clarifiers presented in Tables 2-4 and 2-5 are more appropriate and should be used.

Table 2-15. Parameters for Scoring Capability of Clarifiers in Trickling Filters and RBCs*

Current Operating Condition	Points
Configuration:	
Circular with "donut" or interior launders	10
Circular with weirs on walls	5
Rectangular with 33% covered with launders	5
Rectangular with 20% covered with launders	0
Rectangular with launder at or near end	-10
Surface Overflow Rate, $m^3/m^2/d$ (gpd/sq ft):	
12 (300)	15
20 (500)	10
27 (650)	5
33 (800)	0
41 (1,000)	-10
49 (1,200)	-15
Depth at Weirs:	
3.7 (12)	5
3.0 (10)	3
2.1 (7)	0

* For ABF plants, criteria for suspended growth clarifiers (Table 2-4) should be used.

c. Sludge Handling Capability

Criteria for scoring sludge handling capability associated with fixed film plants are presented in Table 2-16. The criteria for controllability in Table 2-16 are self-explanatory. The capability of sludge handling associated with fixed film facilities is evaluated using the same approach presented in Section 2.3.3.1 for suspended growth POTWs.

Different unit sludge production values are used in calculating expected sludge production from fixed film facilities. Typical unit sludge production values for the various types of fixed film plants are summarized in

Table 2-16. Criteria for Scoring Sludge Handling Capability for Fixed Film POTWs

Current Operating Condition	Points
Controllability:	
Automated sampling and volume control	5
Metered volume and hand sampling	3
Hand measured volume and hand sampling	2
Sampling or volume measurement by hand not practical	0
Capability:	
125% of calculated sludge production	25
100% of calculated sludge production	15
75% of calculated sludge production	5
50% of calculated sludge production	-10

Table 2-17. Unit Sludge Production and Sludge Concentration Values for Projecting Sludge Production From Fixed Film POTWs (1,21,26)

Process Type	kg TSS (sludge)/ kg BOD_5 removed
Trickling Filter	0.9
RBC	1.0
ABF	1.0
Sludge Type:	Waste Conc., mg/l
Primary	50,000
Primary + Trickling Filter	35,000
Primary + RBC	35,000
Primary + ABF	30,000
Trickling Filter	20,000
RBC	20,000
ABF	10,000

Table 2-17. A detailed example of calculating expected sludge production and comparing it with data is included in Section 2.3.5.

Frequently, secondary sludge from fixed film facilities is returned to the primary clarifiers. Typical underflow concentrations of the combined sludge from the primary clarifier are shown in Table 2-17 as well as sludge concentrations from the individual fixed film processes.

The guidelines presented in Tables 2-9 and 2-10 can be used to help an evaluator assess the performance potential of existing sludge treatment and disposal facilities.

d. Fixed Film Major Unit Process Analysis

Worksheets are presented in Appendices M, N, and O to facilitate the fixed film major unit process evaluation. Once major fixed film unit processes are evaluated, they should be summarized and compared to standards for each type of fixed film facility. Tables 2-18, 2-19 and 2-20 can be used for this purpose.

This analysis results in the subject POTW being rated Type 1, 2, or 3, as described in Section 2.3.3.1. Using these tables, the subject plant must score the minimum number of points listed for each individual process and the minimum number total points for all processes for the plant to qualify for a specific plant type. For example, a trickling filter plant scoring the following would meet the criteria for a Type 1 facility for overall points, aerator, and secondary clarifier, but would be classified Type 2 because of its score for sludge handling capability:

	Points Scored	Points Required		
		Type 1	Type 2	Type 3
"Aerator"	21	17-23	0-11	<0
Secondary Clarifier	27	17-30	0-16	<0
Sludge Handling	6	10-30	0-9	<0
Total	54	45-83	15-44	<15

Table 2-18. Trickling Filter Major Unit Process Capability Evaluation

	Points Scored	Points Required*		
		Type 1	Type 2	Type 3
"Aerator"	____	17-23	0-11	<0
Secondary Clarifier	____	17-30	0-16	<0
Sludge Handling	____	10-30	0-9	<0
Total	____	45-83	15-44	<15

* Each unit process as well as the overall points must fall in the designated range for the plant to achieve the Type 1 or 2 rating.

Table 2-19. RBC Major Unit Process Capability Evaluation

	Points Scored	Points Required*		
		Type 1	Type 2	Type 3
"Aerator"	____	14-30	0-13	<0
Secondary Clarifier	____	17-30	0-16	<0
Sludge Handling	____	10-30	0-9	<0
Total	____	48-90	15-47	<15

* Each unit process as well as the overall points must fall in the designated range for the plant to achieve the Type 1 or 2 rating.

Table 2-20. ABF Major Unit Process Capability Evaluation

	Points Scored	Points Required*		
		Type 1	Type 2	Type 3
"Aerator"	____	15-48	0-14	<0
Secondary Clarifier	____	20-55	0-19	<0
Sludge Handling	____	10-30	0-9	<0
Total	____	50-133	15-49	<15

* Each unit process as well as the overall points must fall in the designated range for the plant to achieve the Type 1 or 2 rating.

2.3.3.3 Stabilization Pond Processes

Stabilization pond treatment systems combine the "aerator" function, secondary clarification, and sludge handling into one unit process. Typical pond facilities include facultative and aerobic systems. Process evaluation is based on the relaxed effluent limitation for total suspended solids available for pond systems (e.g., 75 mg/L effluent TSS for facilities less than 2 mgd capacity).

a. Facultative Pond Facilities

The parameters that are used for scoring the capability of facultative stabilization pond facilities and the point system for scoring these parameters is presented in Table 2-21. To obtain the necessary parameters, the evaluator must collect information on wastewater flow, BOD_5 strength, the minimum average winter air temperature, pond dimensions, and the type of flexibility provided with the facility.

Once data are available on these parameters, the following calculations should be completed by the evaluator:

BOD_5 Loading = Influent BOD_5 ÷ Surface Area of All Ponds

(Influent BOD_5 mass is typically the daily average value for the most recent 12 months)

Detention Time = Total Pond Volume ÷ Average Daily Flow

(Flow is typically the daily average value for the most recent 12 months)

To evaluate the possibility of short-circuiting, the following ratios should be calculated:

Short-Circuiting Ratio = Distance From Inlet To Outlet ÷ Maximum Pond Dimension

Length-to-width Ratio = Maximum Pond Dimension ÷ Minimum Pond Dimension

(The ratios for each pond should be calculated, then these values should be averaged)

When the above calculations have been completed for the subject POTW, the results are compared to the values given in Table 2-21 and appropriate points are assigned each parameter. If the parameters for the subject POTW fall between the values listed, interpolation is used to assign appropriate points.

b. Aerated Pond Facilities

The parameters used for scoring the capability of aerobic stabilization pond facilities and the point system for scoring these parameters are presented in Table 2-22. They are similar to parameters used to evaluate facultative facilities with the exception of the

Table 2-21. Parameters for Scoring Capability of Facultative Stabilization Pond Systems* (24,25)

Current Operating Condition	Points
Average Winter Air Temperature >15°C	
BOD_5 Loading, kg BOD_5/ha/d (lb/ac/d):	
45 (40)	10
67 (60)	5
90 (80)	0
112 (100)	-5
134 (120)	-10
1st Pond Loading >101 kg BOD_5/ha/d (>90 lb/ac/d)	-3
Detention Time, days	
30	5
20	0
15	-5
Average Winter Air Temperature 0-15°C	
BOD_5 Loading, kg BOD_5/ha/d (lb/ac/d):	
11 (10)	10
22 (20)	5
45 (40)	0
67 (60)	-5
90 (80)	-10
1st Pond Loading >73 kg BOD_5/ha/d (>65 lb/ac/d)	-3
Detention Time, days	
80	5
30	0
20	-5
Average Winter Air Temperature <0°C	
BOD_5 Loading, kg BOD_5/ha/d (lb/ac/d):	
11 (10)	10
17 (15)	5
22 (20)	0
34 (30)	-5
45 (40)	-5
1st Pond Loading >39 kg BOD_5/ha/d (>35 lb/ac/d)	-3
Detention Time, days	
100	5
50	0
40	-5
Number of Ponds in Series:	
3	5
2 Applies to # ponds in series	0
1	-5
Length to Width Ratio:	
>2	2
1.5-2 Applies to length-to-width	0
<1.5	-2
Ratio of Inlet-Outlet Distance to Max. Pond Dimension (Short Circuiting Ratio):	
>0.75	2
0.5-0.75	0
<0.5	-2
Flexibility to Operate in Series and Parallel:	
Available	3
Not Available	0
Variable Level Draw-Off:	
Available	3
Not Available	-3

* Interpolate to nearest whole number between loadings listed..

oxygen availability and mixing parameters. To obtain the necessary parameters, the evaluator must collect information on wastewater flow, BOD_5 strength, oxygen transfer capacity, mixing energy, pond dimensions, and the type of flexibility provided with the facility. With the exception of oxygen availability and mixing energy, the calculations for these parameters are discussed in Section 2.3.3.3a. For information on evaluating oxygen availability, refer to Section 2.3.3.1.

Table 2-22. Parameters for Scoring Capability of Aerated Stabilization Pond Systems* (24, 25)

Current Operating Condition	Points
BOD_5 Loading, kg BOD_5/ha/d (lb/ac/d): [based on aerated ponds only]	
56 (50)	16
112 (100)	8
168 (150)	0
224 (200)	-5
280 (250)	-10
Detention Time, days	
40	5
15	0
10	-5
Number of Ponds in Series:	
3	10
2	0
1	-10
Length to Width Ratio:	
>2	2
1.5-2	0
<1.5	-2
Ratio of Inlet-Outlet Distance to Max. Pond Dimension (Short Circuiting Ratio):	
>0.75	2
0.5-0.75	0
<0.5	-2
Oxygen Availability, kg O_2/kg BOD_5 load:	
2.0	10
1.5	5
1.2	0
1.0	-5
0.8	-10
Mixing Energy (aerated ponds only), kW/1,000 m^3 (hp/10^6 gal):	
3 (15)	5
2 (10)	3
1 (5)	0
Flexibility to Operate in Series and Parallel:	
Available	3
Not Available	0
Variable Level Draw-Off Discharge:	
Available	3
Not Available	-3

* Interpolate to nearest whole number between loadings listed..

The mixing energy parameter is calculated as follows:

Mixing Energy = Total Energy in Primary Pond ÷ Primary Pond Volume

(Total energy includes energy used for aeration and mixing)

When the above calculations have been completed for the subject POTW, the results are compared to the values given in Table 2-22 and appropriate points are assigned each parameter. If the parameters for the subject POTW fall between the values listed, interpolation is used to assign appropriate points.

c. Stabilization Pond Process Analysis

A worksheet is presented in Appendix P to facilitate the stabilization pond process evaluation. Once the stabilization pond process has been evaluated and given a score, results should be compared with the categories shown in Table 2-23. This analysis results in the subject POTW being rated a Type 1, 2, or 3 facility, as described in Section 2.2.1.1. The sum of the points scored for a facultative pond system must be 16 or above for the subject POTW to be designated a Type 1 facility. For an aerobic pond system the total points scored must be 21 or above for this same ranking. If the subject POTW meets the criteria for a Type 1 plant, the evaluation has projected that the facility has adequate capability within the physical facilities to achieve compliance with the related definition of secondary treatment for pond systems. If the total points for the facility are less than 16 for a facultative pond system or 21 for an aerobic pond system, the facility must be designated as Type 2 or 3.

Table 2-23. Stabilization Pond Process Capacity Evaluation

	Points Scored	Points Required		
		Type 1	Type 2	Type 3
Facultative Facilities	____	>15	0-15	<0
Aerobic Facilities	____	>20	5-20	<5

2.3.4 Evaluation of Performance-Limiting Factors

Identification of performance-limiting factors should be completed at a location that allows all potential factors to be discussed openly and objectively (e.g., away from the plant staff). The checklist of performance-limiting factors presented in Appendix A, as well as the guidelines for interpreting these factors, provide the structure for an organized review of problems in the subject POTW. The intent is to identify as clearly as possible the factors that most accurately describe the causes of limited performance. For example, poor activated sludge operation may be causing poor plant performance because the operator is improperly applying activated sludge concepts. If the operator is solely responsible for process control decisions as well as for testing for these decisions, the factor of improper application of concepts should be identified.

Often, operator inability can be traced to another source, such as an O&M manual containing inaccurate information or a technical consultant who provides routine assistance to the operator. In this case, improper application of concepts plus the source of the problem (O&M manual or inappropriate technical guidance) should be identified as performance-limiting factors, since both must be corrected to achieve desired plant performance.

Whereas the checklist and guidelines in Appendix A provide the structure for the identification of performance-limiting factors, notes taken during the plant tour and detailed data-gathering activities (including the completed forms from Appendix D) provide the resources for identifying these factors.

Each factor identified as limiting performance should be assigned an "A," "B," or "C" rating as discussed in Section 2.2.1.3. Further prioritization is accomplished by completing the summary sheet presented in Appendix B. Only those factors receiving either an "A" or "B" rating are prioritized on this sheet. Additional guidance for identifying and prioritizing performance-limiting factors is provided in the following sections for the general areas of administration, design, operation, and maintenance.

2.3.4.1 Administration Factors

Budgeting and financial planning are the mechanisms whereby POTW owners/administrators generally implement their objectives. Therefore, evaluation and discussion of these aspects is an integral part of efforts to identify the presence of administrative performance-limiting factors. For this reason, early during the on-site fieldwork, the evaluator should schedule a meeting with the key POTW decision-maker and the "budget person." This meeting should be scheduled after the evaluator is familiar with the plant.

Nearly every POTW's financial information is set up differently so it helps to review the information with the assistance of plant personnel to realistically rearrange the line items into categories understood by the evaluator. Forms for collecting financial data are presented in Appendix D. Analysis of these data can be supported by comparison with typical values for wastewater treatment plants (16,20,21). POTWs with flows greater than 88 L/s (2 mgd) usually have separate financial information for the wastewater treatment facilities. Smaller POTWs often have financial information combined with other utilities, such as wastewater collection, water treatment and distribution, or even street repairs and maintenance. For this reason, it is often more difficult and time consuming to assess the financial status for small POTWs.

Key POTW administrators should be identified and individual interviews scheduled with them as described in Section 2.3.3.1. As a general rule, the individual interviews should be held in an environment that allows for open discussion.

The evaluation of administrative performance-limiting factors is by nature subjective. Typically, all administrators verbally support goals of low costs, safe working conditions, good treatment performance, high employee morale, etc. An important question that the evaluator must ask is, "Where does good treatment fit in?" Often this question can be answered by observing the priority of items implemented or supported by administrators. The ideal situation is one in which the administrators function with full awareness that they want to achieve desired performance as an end product of their wastewater treatment efforts. Improving working conditions, lowering costs, and other similar goals would be pursued within the realm of first achieving adequate performance.

At the other end of the spectrum is an administrative attitude that "we just raised the monthly rates 100 percent last year; we can't afford to spend another dime on that plant." POTW administration can be judged by the following criteria:

Excellent: Reliably provides adequate wastewater treatment at lowest reasonable cost.

Normal: Provides best possible treatment with the money available.

Poor: Spends as little as possible with no correlation made to achieving adequate plant performance.

Administrators who fall into the "poor" category typically are identified as contributing to inadequate performance during the factor identification activities.

Technical problems identified by the plant staff or the CPE evaluator, and the potential costs associated with correcting these problems, often serve as the basis for assessing administrative factors limiting plant performance. For example, the plant staff may have correctly identified needed minor modifications for the facility and presented those needs to the POTW administrators, but had their request turned down. The evaluator should solicit the other side of the story from the administrators to see if the administrative policy is indeed non-supportive in correcting the problem. There have been many instances in which operators or plant superintendents have convinced administrators to spend money to "correct" problems that resulted in no improvement in plant performance.

Another area in which administrators can significantly, though indirectly, affect plant performance is through personnel motivation. A positive influence exists if administrators encourage professional growth through support of training, tangible awards for initial or upgrading certification, etc. If, however, administrators eliminate or skimp on essential operator training, downgrade operator positions through substandard salaries, or otherwise provide a negative influence on operator morale, administrators can have a significant detrimental effect on plant performance.

2.3.4.2 Design Factors

Data gathered during the plant tour, completion of forms in Appendix D, and the completed evaluation of major unit process capabilities provide the basic information needed to complete the identification and prioritization of design-related performance-limiting factors. Often, to complete the evaluation of design factors, the evaluator must make field investigation of the operational flexibility of the various unit processes.

Field investigations should be completed in cooperation with the POTW operator. The evaluator must not make any changes unilaterally. Any field testing desired should be discussed with the operator, whose cooperation should be obtained in making any needed changes. This approach is essential since the evaluator may wish to implement changes that, while improving plant performance, could be detrimental to specific equipment at the plant. The operator has worked with the equipment, repaired past failures, and read the manufacturers' literature, and is in the best position to ascertain any adverse impact of proposed changes.

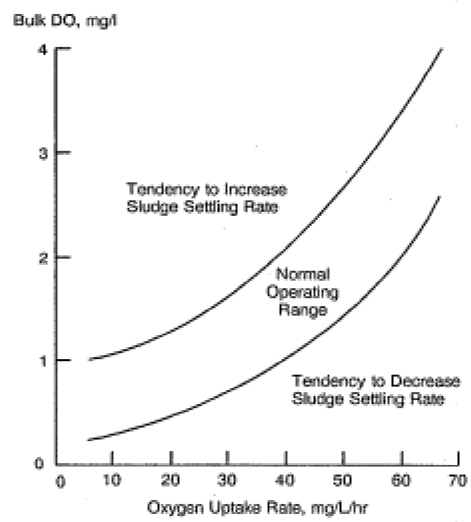
Field investigation of process flexibility defines the limitations of the equipment and processes and also promotes a better understanding of the time and difficulty required to implement better process control. This is illustrated by the following discussion:

> A 4.4-L/s (0.1-mgd) extended aeration facility has airlift sludge return pumps that have been operated to provide return rates of 200-300 percent of influent flow rates. The evaluator desired to know if returns could be held under 100 percent since this would substantially reduce solids loading on the final clarifier and potentially improve clarifier performance.
>
> Discussions with the plant operator revealed that he had previously tried to reduce the return rate by reducing the air to the airlift return pumps. The operator abandoned the idea because the airlifts repeatedly plugged overnight when left at the lower rates. The evaluator convinced the operator to again try reducing the return rate so that the limits of return sludge flow control available could be defined.
>
> Air flow rate was initially reduced to produce a return flow rate of 100 percent of incoming wastewater flow as measured by a bucket and stopwatch. The airlift return pumps plugged completely in less than 2 hours. The return flow rate was reset to 100 percent by increasing the airflow substantially above the previous setting. An hour later the return flow rate was measured as 220 percent. These results supported the operator's contention that return flow rates could not be controlled at reasonable levels.
>
> The air supply was again adjusted to provide a flow rate halfway between the current and the desired rate. This setting allowed better control to be exercised, but plugging still occurred with existing sludge characteristics at return sludge flows of less than about 125 percent. It was concluded that this was the practical lower limit for return sludge flow rate control with the existing facilities and sludge character. To maintain a return sludge in the range of 125-150 percent required frequent checking, including an evening check not before asked of the operator. In this manner, part - but not all - of the design limitation could be overcome with increased operator attention.

The areas in a POTW that frequently require field investigations to determine process flexibility are:

1. *Suspended Growth Systems*
   - Control of return sludge flow rate within the ranges presented in Table 2-5
   - Control of aeration basin DO within the ranges presented in Figure 2-2
   - Sludge mass control by wasting expected sludge production (mass and volume) presented in Tables 2-7 and 2-8
   - Flow splitting to prevent unnecessary overloading of individual process units

Figure 2-2. Effect of aeration basin DO concentrations on sludge settling characteristics.



- Available mode changes to provide maximum use of existing facilities:
  - Step feed or contact stabilization when the final clarifier appears to be a limiting unit process
  - Step feed when oxygen transfer is marginal

2. *Trickling Filters*
   - Alternate disposal methods for anaerobic digester supernatant
   - Ability to control sludge levels in clarifiers without adversely impacting sludge handling facilities
   - Recirculation to the filter without excess hydraulic loads on the primary or secondary clarifiers

3. *RBCs*
   - Alternate disposal methods for anaerobic digester supernatant
   - Ability to control sludge levels in clarifiers without adversely impacting sludge handling facilities
   - Ability to redistribute individual stage loadings to provide unit loadings within the ranges shown in Table 2-13

4. *ABFs*
   - Control of return sludge flow rates within 50-100 percent of influent flow
   - Ability to waste a desired mass of sludge on a daily basis
   - Ability to spread a day's sludge wasting over a 24-hour period, or at least an extended period of time
   - Ability to provide recirculation directly around the biocell
   - Ability to maintain aeration basin DO at 2-3 mg/L

2.3.4.3 Operational Factors

Operational factors are those factors that relate to the unit process control functions implemented at a POTW. Significant performance-limiting factors often exist in these areas (16). The approach and methods used in maintaining process control can significantly affect the performance of plants that have adequate physical facilities. This section provides guidance to evaluators for identification and prioritization of operational factors that limit plant performance.

The evaluator starts collecting data for the process control evaluation by identifying the key POTW person for process control strategies implemented at the plant. The plant tour and data-gathering phases also provide opportunity to assess the process control applied. In addition, the process control capability of an operator can be subjectively assessed during the major unit process evaluation. If an operator recognizes the unit process functions and their relative influences on plant performance, a good grasp of process control is indicated. An approach to evaluating process control is discussed in the following sections.

a. Suspended Growth Facility Process Control

The process controls that should be available to an operator of an activated sludge facility are control of: sludge mass, aeration basin DO, and return sludge rate. Techniques and approaches to improving these controls are presented in Chapter 3.

Sludge Mass Control

The activated sludge process removes colloidal and dissolved organic matter from wastewater resulting in a net increase in the sludge solids in the system. Control of the amount of sludge maintained in the system by wasting (removing) excess sludge is a key element in controlling plant performance. All variations of the activated sludge process require sludge mass control and periodic wasting. In line with this requirement, an operator who properly understands activated sludge mass control should be able to show the evaluator a recorded history of a controlled sludge mass (e.g., records of mean cell residence time [MCRT], mixed liquor volatile suspended solids [MLVSS], plots of MLSS/MLVSS concentrations in the aeration basin, total mass of sludge in the plant, etc.).

The following are common indicators that sludge mass control is not adequately practiced at an activated sludge plant:

- A sludge mass indicator parameter or calculation (MLVSS, MCRT, total sludge units) is not obtained on a routine basis (22). "Routine" would be at least daily for an 88-L/s (2-mgd) or larger plant and 2-3 times a week for a 4.4-L/s (0.1-mgd) plant.
- Only a settled sludge test is used to determine wasting requirements (e.g., waste if the 30-minute settled sludge volume in a graduated cylinder is greater than 600 ml/L).
- The operator does not relate mass control to control of sludge settling characteristics and sludge removal performance (i.e., sludge character).
- Significantly less mass is wasted than calculations indicate should be produced (i.e., the clarifiers lose solids over the weirs routinely).
- Poor performance persists and the mass of sludge maintained provides an MCRT significantly out of the ranges in Table 2-24.

Table 2-24. Typical Mean Cell Residence Times for Suspended Growth POTWs

Process Type	Typical MCRT
	days
Conventional Aeration	4-12
Extended Aeration	20-40
Contact Stabilization	10-30

Aeration Basin DO Control
The aeration basin DO level is a significant factor in promoting the growth of either filamentous or zoogleal-type sludge organisms (23). Higher DO tends to speed up or slow down the relative populations of these major organism types toward primarily zoogleal. Conversely, lower DO encourages the growth of filamentous organisms and a bulky, slow settling sludge. A general guideline for relating sludge characteristics to DO concentration in an aeration basin is presented in Figure 2-2. This information can be used to evaluate the DO control approach at the POTW under study.

The following are common indicators that aeration basin DO control is not properly practiced at an activated sludge plant:

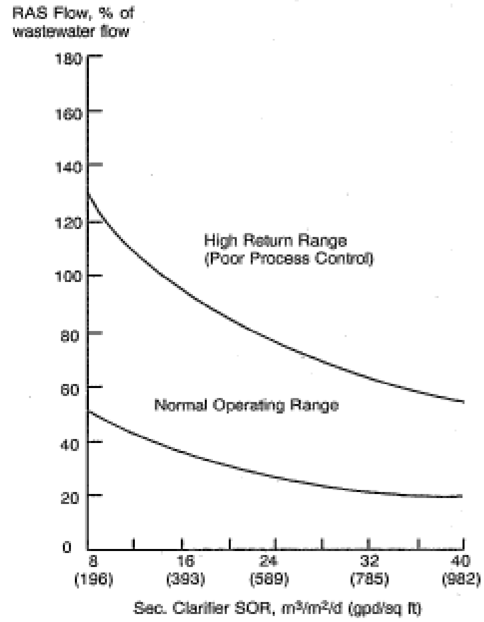
- DO testing is not run routinely on the aeration basin. "Routine" ranges from daily for an 88-L/s (2-mgd) or large plant to weekly for a 4.4-L/s (0.1-mgd) plant.
- The operator does not understand or use the relationship between DO and sludge character (e.g., sludge settling is very slow and DO is very low, or sludge settling is very fast, effluent is turbid, and DO is very high).

Return Sludge Control
The objective of return sludge flow control is to optimize sludge distribution between the aerator and secondary clarifier to achieve and maintain good sludge characteristics. Thus, return sludge flow rate control should be used to maximize the sludge mass and sludge detention time in the aeration basins and minimize the sludge mass and sludge detention time in the clarifiers.

The following are common indicators that return sludge flow rate control is not properly practiced at an activated sludge plant:

- Returns are operated outside the ranges (especially higher) indicated in Table 2-5 and Figure 2-3.
- The operator believes that a high sludge blanket condition in a final clarifier can be categorically lowered by increasing the sludge return rate. (E.g., the operator does not realize that increasing the return sludge flow rate increases the solids loading to the final clarifier and decreases the settling time in the final clarifier.)

Figure 2-3. Typical return sludge flow rates with various clarifier surface overflow rates.



- MLSS concentrations fluctuate widely on a diurnal basis, but return rates are not adjusted throughout the day to account for diurnal flow variations.
- The operator has not devised a method to estimate or measure the return sludge flow rate if measurement was not provided for in the original design.

b. Fixed Film Facility Process Control
There is a lesser amount of process control that can be applied to fixed film facilities than to suspended growth facilities. However, because fixed film facility performance is so dependent on media loading, process control, which may at first seem unimportant, can make a significant difference in plant performance. The following are common indicators that process control at a fixed film facility is not optimum (1):

- Sludge blankets in either the primary or secondary clarifiers are maintained at a high level [i.e., >0.3 m (1 ft)].
- Organic loads from return process streams are not minimized.

- Lack of good maintenance, indicated by:
  - Distributors on trickling filters are plugged, or leaky distributor seals are not fixed.
  - Filter media is partially plugged and measures such as chlorination, flooding, and recirculation are not used to address the problem.
  - Trickling filter underdrain collector outlets are submerged or air vents are plugged.
- High recirculation, which increases primary or secondary clarifier overflow rates, is provided without regard to clarifier overloading. Some trickling filter plants provide recirculation that is directed to the influent wastewater wet-well and must pass through the primary clarifier a second time. Likewise, some trickling filters provide recirculation through the secondary clarifier sludge return to the head of the plant. Recirculation provided by these methods should not be practiced.

2.3.4.4 Maintenance Factors

General information on POTW maintenance is gathered during the detailed data collection phase and is recorded on Form D-5. However, the evaluation of maintenance performance-limiting factors is done throughout the CPE by observation and questions concerning the reliability and service requirements of pieces of equipment critical to process control and thus performance. If units are out of service routinely or for extended periods of time, maintenance practices may be a significant contributing cause to a performance problem. An adequate spare parts inventory is essential to a good maintenance program. Equipment breakdowns are often used as excuses for process control problems. For example, one operator of an activated sludge plant blamed the repeated loss of sludge over the final clarifier weirs on the periodic breakdown of one sludge return pump. Even with one pump out of service, the return sludge capacity was over 200 percent of influent flow. The real cause of the sludge loss was improper process control, including inadequate sludge mass control and excessively high return sludge flow rates.

Observation and documentation are necessary portions of the approach utilized to evaluate emergency and preventive maintenance practices. Important aspects are examination and verification of spare parts inventories and recordkeeping systems. An example approach to a preventive maintenance scheduling system that has been applied successfully at several plants is presented in Appendix G. A good preventive maintenance program includes a schedule to distribute the workload evenly. Evaluation of these items provides a basis from which the specific results of maintenance, or lack thereof, can be assessed. This approach is illustrated by the following:

> A poorly performing trickling filter plant was assessed to have acceptable BOD_5 loadings to the filter, capable secondary clarifiers, and adequate sludge handling facilities. However, a large buildup of sludge was maintained in both the primary and secondary clarifiers. Questioning of the operator revealed that sludge was not removed adequately because the heated anaerobic digesters were upset if too much sludge is added. Further investigation indicated that adequate temperature control of the digester contents was not being achieved. The operator pointed out that the boiler for the heat exchanger was operated manually and just during the day because he had tried unsuccessfully to fix the automatic controls. Ultimately, inadequate maintenance was identified as a cause of poor plant performance.

The above discussion illustrates how a detailed evaluation of process control activities was necessary to properly identify a maintenance-related factor as a cause of poor plant performance. The evaluator must evaluate maintenance during all phases of the CPE and should not expect to identify these factors solely in a formal evaluation of maintenance procedures.

2.3.5 Performance Evaluation

The plant performance evaluation is directed toward two goals: 1) establishing, or verifying, the magnitude of a POTW's performance problem; and 2) projecting the level of improved treatment that can be expected.

2.3.5.1 Magnitude of the Performance Problem

During the CPE, the evaluator should develop a clear understanding of the performance problem associated with the subject POTW. As a first step of this assessment, recorded historical performance data can be used. These data are available from copies of NPDES permit reports in small POTWs and from monthly monitoring summary sheets in larger POTWs.

Once historical data are reviewed, the evaluator should attempt to verify the accuracy of the reported plant performance. It should be stressed that the purpose is not to blame the plant staff, but rather to assist in identifying and substantiating the true cause(s) of poor plant performance.

The evaluator can indirectly collect data to establish authenticity of the monitoring results throughout the CPE. For example, major unit processes are assessed for their capability to achieve desired performance. If a POTW is rated a Type 3 plant (inadequate major process capability), reported excellent effluent quality should be suspect. If reported performance is consistent with the results of the overall evaluation, the validity and accuracy of the data are reinforced.

Limitations of these comparisons are their subjective nature.

Major test parameters critical for completion of the CPE are influent BOD_5 and flow. The evaluator can roughly check both BOD_5 and flow data by calculating a per capita BOD_5 contribution. Per capita BOD_5 contributions are usually 0.07-0.09 kg (0.15-0.20 lb)/d for typical domestic wastewater. When estimating BOD_5 loads to a plant without actual data, or checking reasonableness of existing plant data, loads from significant industrial contributors must be added to the calculated per capita loads.

Small activated sludge plants have been shown to have the most variance between historical records and actual performance. In small activated sludge plants - such as package extended aeration plants, contact stabilization plants, and oxidation ditches - several days' or even an entire week's sludge production can be lost as the result of sludge bulking in several hours. Effluent TSS may be less than 10 mg/L before and after bulking occurs, but may reach 1,000-2,000 mg/L while bulking. The operator has ample opportunity between bulking periods to collect more than enough samples to meet permit monitoring requirements and indicate a good effluent quality.

Another sampling procedure that can result in nonrepresentative monitoring is sometimes seen in fixed film facilities where performance degrades significantly during peak daytime loads. Samples collected from 6 a.m. to 10 a.m. may meet the required compositing criteria (e.g., three samples at 2-hour increments), but would probably indicate better than overall average effluent quality. Likewise, samples collected from noon to 4 p.m. may indicate worse than actual average effluent quality.

To verify good data or determine the magnitude of a performance problem, a comparison of expected vs. actual sludge production should be made during the CPE. This comparison has proven invaluable in conducting a CPE and is termed a Sludge Accountability Evaluation. A detailed example of this evaluation is presented.

a. Example Sludge Accountability Evaluation
A 44-L/s (1-mgd) oxidation ditch activated sludge plant is bring evaluated. The plant's NPDES discharge monitoring reports indicate that the plant is in compliance. Information collected during the CPE is as follows:

- The plant operator felt the final clarifier was not large enough to capture all the solids during high flows - he suggested that a flow equalization basin be constructed.
- The plant has 1 oxidation ditch, 2 final clarifiers, 1 chlorine contact tank, and 6 sludge drying beds.
- The plant has limited infiltration/inflow (I/I) and no significant industrial waste contribution. I/I occurs in the early spring, causing the highest average monthly flow to be about 20 percent greater than the annual average flow.
- The City Clerk reported that there were 3,520 taps that were billed quarterly.
- The plant does not have return sludge flow measurement. Two constant-speed return sludge pumps are available to return sludge to the oxidation ditch. Both pumps are being operated at full speed to "get the solids out of the clarifier and back to the oxidation ditch." The R/Q ratio was estimated to be greater than 500 percent by measuring the return sludge flow rate utilizing draw-down of the final clarifier. Return sludge flow can be reduced by adjusting a plug valve on the discharge side of the pump, and by operating 1 of the 2 pumps. It is difficult to operate the pump at lower flow rates because the valve plugs with rags.
- Excellent laboratory facilities were available and the operators run all tests required by the NPDES permit. These include tests for: plant influent and effluent BOD_5 and TSS; plant effluent residual chlorine; and fecal coliform. Oxidation ditch MLSS tests are run once per week along with a settling test in a graduated cylinder to determine SVI.
- The plant superintendent reported that he wasted sludge to his drying beds when he had trouble keeping the sludge in the final clarifiers.
- The population of the community was estimated by the Mayor to be about 8,500.
- Influent plant flow was checked by measuring the depth of flow in the Parshall flume and comparing the calculated flow to the flow indicator. The reading was within 10 percent of the measured flow.
- The plant superintendent said that he "filled up" all of his drying beds "about 10 times" last year. There are 6 beds, each measuring 100' x 50' x 18" deep.
- NPDES permit monitoring requirements and plant effluent limits are as follows:
- Plant performance data are shown in the table below:

<u>Plant Loading Evaluation</u>
Plant loadings should be verified by comparison to typical per capita contributions for domestic wastewater. Since industrial loadings can significantly effect this evaluation, plants where significant

Parameter	Permit Limits 30-day avg.	7-day avg.	Monitoring Requirements Frequency	Sample Type*
Influent BOD_5	-	-	Monthly	Composite
Effluent BOD_5	30 mg/L	45 mg/L	Monthly	Composite
Influent TSS	-	-	Monthly	Composite
Effluent TSS	30 mg/L	45 mg/L	Monthly	Composite
Effluent pH	6.5-9	6.5-9	Weekly	Grab
Fecal Coliform	200 per 100 mL	400 per 100 mL	Monthly	Grab

* A composite sample is defined as being comprised of a minimum of 4 samples collected 2 hours apart with the individual sample volume being proportioned to plant flow.

Performance Data for Example Sludge Accountability Evaluation

Date	Raw Flow, mgd[1]	BOD_5, mg/L[2]	TSS, mg/L[2]	BOD_5 Load, lb	Final Effluent[3] BOD_5, mg/L[2]	TSS, mg/L[2]
6/84	0.791	276	290	1,820	8	10
7/84	0.762	281	205	1,785	7	12
8/84	0.781	270	232	1,758	5	11
9/84	0.720	274	190	1,645	7	12
10/84	0.759	251	237	1,589	4	9
11/84	0.747	225	241	1,402	9	10
12/84	0.715	231	187	1,377	7	9
1/85	0.729	197	215	1,198	6	9
2/85	0.761	263	217	1,669	4	10
3/85	0.813	201	245	1,363	7	14
4/85	0.938	173	198	1,353	11	18
5/85	0.880	197	220	1,446	9	16
Avg.	0.783	237	223	1,534	7	12

[1] Flow recorded daily.
[2] Based on one composite sample/month. Composite sampling usually done on Thursday. Samples collected at 8:00 am, 9:00 am, 11:00 am, and 1:00 pm. Influent BOD_5 and TSS values may be high since this is the peak load period of the day.
[3] The operator reported the need for flow equalization since, during high flows, some solids were lost. No indication of solids loss is apparent in plant effluent data.
Source of Data: Plant NPDES Monitoring Records

industrial contributions are known to be present cannot be evaluated in this manner.

1. *Population Served* (assume 2.5 persons/tap).

(2.5 persons/tap) x (3,520 taps) = 8,800 people

Use average of reported population and estimated population:

(8,500 + 8,800) ÷ 2 = **8,650 people**

2. *Plant Flow Evaluation* (assume 100 gal/capita/d for typical domestic wastewater).

Projected plant flow = 8,650 x 100 = 865,000 gpd
Measured plant flow = **783,000 gpd**

Conclusion: measured plant flow appears to be within expected range - therefore use actual plant flow in evaluation.

3. *Organic Loading Evaluation* (assume 0.15-0.20 lb BOD_5/capita/d for typical domestic wastewater - use 0.17).

Projected plant organic load = 8,650 x 0.17
= **1,471 lb BOD_5/d**

Plant organic load from plant data = 1,534 lb BOD_5/d

Conclusion: plant BOD_5 data is higher than projected BOD but sampling is during peak load portions of the day - use projected organic load.

Calculated influent BOD_5:

(1,471) ÷ (8.34 x 0.783) = **225 mg/L**

<u>Sludge Accountability Evaluation</u>
1. Determine anticipated sludge production.

BOD_5 conc. removed = 225 - 7 = 218 mg/L

BOD_5 mass removed = 218 (0.783) (8.34)
= 1,424 lb BOD_5/d

From Table 2-7, expected lb TSS (sludge)/lb BOD_5 removed = 0.65 for an oxidation ditch. Therefore:

Expected sludge = 0.65 (1,424) (365)
= **337,990 lb/yr**

2. Estimate Accounted-For Sludge Wasted From Plant.

Effluent "Waste Sludge" = (0.783)(12)(8.34)(365)
= 28,602 lb/yr

Intentionally Wasted Sludge (operator said he filled sludge beds "about ten times" last year):

Sludge bed volume = (6 beds) (100') (50') (18"/12)
= 45,000 cu ft

Waste sludge volume = (10 times) (45,000) (7.48)
= 3,366,000 gal/yr

From Table 2-8, expected waste sludge concentration is 7,500 mg/L. (Assume that return sludge flow can be controlled within a reasonable range.) Therefore:

Wasted Sludge = 3.366 (7,500) (8.34)
= 210,543 lb/yr

Total Accounted-For Sludge = 28,602 + 210,543
= **239,145 lb/yr**